Hybrid Electric Vehicles— Power Unit Technologies

The hybrid power unit (HPU) has various functions depending on the configuration of the HEV. In a parallel hybrid, the HPU drives the wheels through a transaxle; in a series, it drives an alternator to produce electricity. The candidates for the HPU function in an HEV consist of internal combustion engine technologies and fuel cells as a possible attractive longer-term possibility. Fuel use in these engines is another variable, with reformulated gasoline, natural gas, alcohols, and other alternative fuels impacting both emissions and driving performance.

Important factors in considering HPU technologies for HEV applications include high energy efficiency, reduced emissions (in relation to current and future standards), and good transient response. The ability to use diverse fuels and specific power and power density equal to or higher than that of conventional engines

are also important factors. Other applications to consider include noise and vibration reduction, reliability, durability, maintenance experience, operating costs, and safety levels equal to or superior to current levels.

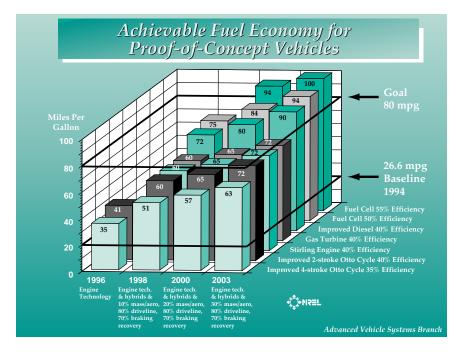
Information on some promising alternatives to the standard Otto cycle four-stroke engine for HEV applications is as follows:

Gas turbine engine

The gas turbine does not appear to be a viable automotive propulsion system on its own, largely because of its poor transient response time. However, in a series HEV application where the engine would be driving a generator and operating within a narrower speed range, this weakness is less of an issue. Potentially the gas turbine could offer a number of advantages, including extremely low emissions, small size, low maintenance, reduced

noise and vibration, good thermal efficiency, fuel flexibility, and simplicity of design.

A critical barrier to the success of the automotive gas turbine is the lack of cost-effective, reliable ceramic materials that can operate effectively and for long durations at turbine inlet temperatures of up to 2,500° F. Developing these materials is a focus of the U.S. Department of Energy's (DOE) Hybrid Vehicle



Power Unit Technologies

Turbine Engine Technology Support Program and Ceramic Turbine Engine Demonstration Program. These programs are among many related DOE-sponsored efforts that support the core hybrid teams.

Compression ignition engine

Progress continues to be made in advancing the Compression ignition, direct-injection (CIDI) engine, (more commonly called the diesel engine), which has the highest thermal efficiency of any internal combustion engine. Challenges include a lower specific power than the gasoline engine; significant particulate matter and nitrogen oxides in the exhaust; and the noise, vibration, and smell of the engine, which are generally considered as negatives.

Recent advancements in European high-speed automotive diesel engines that address some of these shortcomings have made them nearly ideal candidates for HEV applications. These advancements include high-pressure direct fuel injection, low NOx catalysts, and sophisticated electronic controls. With a thermal efficiency greater than 40% and well-understood maintenance, reliability, manufacturing, and operating characteristics, the high-speed CIDI engine shows great promise as a near-term hybrid HPU.

Stirling engine

The Stirling cycle external combustion engine has certain characteristics that make it a potential candidate for the HEV. Among these are high thermal efficiency, potential for low emissions, and low noise. The principal disadvantage is low power density due to external combustion and large heat rejection requirements. In addition, there is little experience with Stirling engines in automotive applications; most working knowledge of the technology is in aerospace and cryogenic cooling applications.

Previous work sponsored by DOE has shown that the transient response of the engine is poorly matched to conventional drivetrain vehicle demands. For a series hybrid, this constraint would be mitigated; thus the engine is potentially attractive in some HEV applications.

Fuel cells

Fuel cells generate electricity through an electrochemical reaction combining hydrogen with ambient air. They can utilize pure hydrogen or any onboard fossil fuel that is "reformed" to produce a hydrogen-rich gas. Methanol is a common fuel choice.

For the most part, the fuel cell's only emission is water vapor, making it the potentially cleanest HPU alternative, as well as efficient, quiet, and reliable. Fuel cells are predicted to demonstrate energy conversion efficiencies greater than 50%, very high in comparison to the 20-25% efficiency of standard gasoline engines.

The choice of fuel for a fuel cell-powered HEV has important implications for required infrastructure, system accessories, efficiency, cost, and design. Although its viability has been well proven in the space program, as well as in prototype vehicles developed by DOE and industry partners, very high capital costs, large size, long start-up times, and immature technologies place it as a longer-term enabling technology for a commercializable HEV.

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